(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 373 974 A2**

(12) **EUROPEAN PATENT APPLICATION**

(21) Application number: 89401757.3

(51) Int. Cl.5: D04H 1/44

(22) Date of filing: 22.06.89

(30) Priority: 15.12.88 US 284534

(43) Date of publication of application: 20.06.90 Bulletin 90/25

(84) Designated Contracting States: AT BE CH DE ES FR GB GR IT LI LU NL SE

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(54) Method of preparation of a highly absorbent nonwoven fabric.

(57) A strong, highly absorbent hard finished nonwoven toweling fabric consisting of wood pulp and textile fibers essentially free from added binders is prepared by forming a wet-laid web of a blend of fibers containing 30 to 80 weight percent wood pulp and 20 to 70 weight percent staple length fibers subjecting the fibers in the wet-laid web to hydroentanglement, and embossing the hydroentangled web. The embossed fabric may be apertured or essentially nonpertured, and may be made lint resistant or water repellant or both. The fabric may be converted into pads or towels having medical and surgical applications, or into household cloths, food service wipes, industrial machinery wipes or the like.

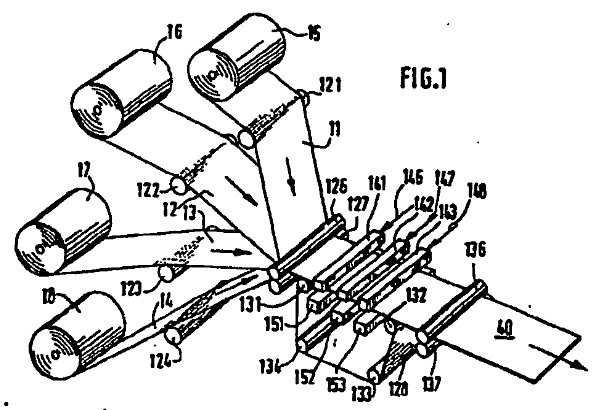

FIG.1

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METHOD OF PREPARATION OF A HIGHLY ABSORBENT NONWOVEN FABRIC

This invention relates to a method of preparation of highly absorbent hydroentangled nonwoven fabrics containing wood pulp and textile length fibers.

Composite webs made up of various combinations of fibers are known in the prior art. Nonwoven fabrics in which staple length textile fibers are hydroentangled with continuous filaments are disclosed in U.S. 3,494,821 and 4,144,370. In U.S. 3,917,785, staple rayon fibers are blended with wood pulp, supported on an impermeable patterned support, and subjected to the force of water from jets to hydroentangle the fibers and form an apertured fabric. In U.S. Patent Nos. 3,917,785 and 4,442,161, a layer of textile fibers, which may be mixed with wood pulp, is supported on a foraminous screen and hydroentangled by means of hydraulic jets to form a non-woven fabric.

Nonwoven fibrous webs comprising mixtures of wood pulp and synthetic fibers have high moisture absorption capabilities and may be inexpensively produced by conventional papermaking procedures. However, such products also tend to have relatively low wet strength properties and lack sufficient strength for many applications, for example, for use as surgical towels, household cloths, food service wipes and industrial machinery wipes. The strength of such products may be improved by including a bonding agent in the fiber furnish or by application of an adhesive binder to the formed web. While the strength characteristics of the web are improved by use of an adhesive binder, such as a synthetic resin latex, the liquid absorption capability of the web is correspondingly decreased.

We have now discovered that a high strength, nonwoven highly absorbent fabric having visual and clothlike hand characteristics of a woven towel and superior moisture absorption may be produced from a homogeneous blend of 30 to 80 weight percent wood pulp and 20 to 70 weight percent long synthetic fibers by forming first a wet laid web or blanket of the fibers in the desired relative proportions and subjecting the wet laid web to hydroentanglement with sufficient energy to form a relatively dense, cohesive, uniform fabric. This fabric is then embossed at room temperature between two matched, interpenetrating dies. In one specific embodiment of this invention, a wet laid web of wood pulp and staple synthetic staple fibers is formed in known manner, dried, and, subjected to hydraulic entanglement. As a specific example, wetlaid webs having a total basis weight of 3 to 5 ounces per square yard (102 to 170 g/m^2) made up of 50 to 75 weight percent wood pulp and 25 to 50 weight percent polyester fibers hydroentangled at an energy output of the order of 10,000 KPa produces a strong nonwoven fabric having superior water absorption qualities as compared with woven cotton huckaback towels and after being embossed as disclosed herein, comparable hand characteristics with clothlike softness and texture.

The nonwoven fabrics of this invention containing a substantial proportion of wood pulp are strong when wet and highly absorbent, and do not require stabilization with a latex adhesive. The staple length fiber may be produced by known methods from any of various synthetic resins including polyolefins, nylons, polyesters, and the like ; polyester fibers are preferred.

In accordance with the present invention, the synthetic textile fibers are blended with wood pulp and formed into a web by a wet-laying process technique as utilized in the paper and nonwovens industries. One or more such composite wet-laid webs are then subjected to hydraulic entanglement producing a uniform spunlaced composite fabric with superior water absorption properties. A preferred method and apparatus for hydraulically entangling the fibers is disclosed in U.S. Patent No. 3,494,821, incorporated herein by reference.

Preferably, the composite wet-laid web is produced by a conventional wet-laid papermaking method by dispersing a uniform furnish of wood pulp fibers and staple synthetic fibers onto a foraminous screen of a conventional papermaking machine. U.S. Patent No. 4,081,319 to Conway and U.S. Patent No. 4,200,488 to Brandon et al. disclose wet-laying methods which may be used to produce a uniform web of wood pulp and staple fibers. A preferred method of dispersing a mixture of staple fibers and wood pulp is disclosed in commonly assigned copending U.S. Patent Application Serial No. 07/035,059 filed April 6, 1987.

While various wood pulps may be incorporated into the finished fabric by the method disclosed herein, those pulps which are characterized by long, flexible fibers of a low coarseness index are preferred. Wood fibers with an average fiber length of three to five millimeters are especially suited for use in the spunlaced fabrics. Western red cedar, redwood and northern softwood kraft pulps, for example, are among the more desirable wood pulps useful in the nonwoven spunlaced fabrics of the invention.

Staple fiber length is an important factor affecting the strength and abrasion resistance of the resulting fabric. Staple fibers which are either too short or too long do not entangle as well as those in the range of from about one-quarter inch to about one inch with a diameter range of 0.5 to 3 denier. Staple fibers in the range of one-half inch to seven-eighths inch in length and a diameter in the range of 0.5 to 2.9 denier are

preferred for use in the process of this invention. Shorter staple fiber lengths in the range of from about one-quarter to one-half inch result in lowered tear strength of the finished product. The staple fibers may be round, elliptical, or scalloped oval in cross section.

The wood pulp content of the improved nonwoven web produced in accordance with the present invention may be in the range of from about 30 weight percent to about 80 weight percent. For most applications, a wood pulp content in the range from about 55 weight percent to 65 weight percent is preferred. The higher levels of wood pulp impart increase absorbency of the product, but usually result in some loss of abrasion resistance, and tensile strength.

In carrying out the process of the present invention, the entangling treatment described in the prior art, for example, by the hydroentanglement process disclosed in U.S. Patent No. 3,485,706 to F. J. EVANS, or 3,560,326 to Bunting, Jr., et al., incorporated herein by reference, may be employed. As known in the art, the product fabric may be patterned by carrying out the hydroentanglement operation on a patterned screen or foraminous support. Nonpatterned products also may be produced by supporting the layer of layers of fibrous material on a smooth supporting surface during the hydroentanglement treatment as disclosed in U.S. Patent No. 3,493,462 to bunting, Jr., et al.

The basis weight of the finished fabric may range from about 1 ounce per square yard (34 g/m^2) to about 10 ounces per square yard (340 g/m^2). The lower limit generally defines the minimum weight at which acceptable water absorption and web strength can be attained. The upper limit generally defines the weight above which the water jets are not effective to produce a uniformly entangled web.

The wet-laid web may be produced on-site and fed directly from the web-forming apparatus to the hydroentangling apparatus without the need for drying or bonding of the web prior to hydroentanglement. Alternatively, the wet-laid composite web may be produced at a separate site, dried and supplied in rolls to the site of the hydroentanglement device.

The separately formed wet-laid web containing the staple length textile fibers and wood pulp fibers is hydroentangled by water jets while supported on a foraminous screen or belt, preferably one made up of synthetic continuous filaments woven into a screen. The web is transported on the screen under several water jet manifolds of the type described in U.S. Patent No. 3,485,706. The water jets entangle the discrets staple fibers and wood fibers present in the wet-laid web producing an intimately blended strong absorbent composite fabric. After drying, and embossing with matched dies at room temperature, the resulting fabric is soft and is a suitable material for conversion to surgeon's hand towels, and other products useful in disposable personal care or health care applications, or as a durable, multiple use products. Food service wipes, domestic hand towels or dish towels, and other utility wipes made up of spunlaced synthetic staple fibers and wood pulp are stronger, more absorbent and genrally superior in service to cloth toweling and similar products made up of hydroentangled rayon bonded with latex or those made of scrim reinforced cellulose tissue.

Colored fabrics may be made up from dyed wood pulp, or dyed or pigmented textile staple fibers or both.

The fabric may be sterilized by currently known and commercially available sterilization processes, e.g., gamma irradiation, ethylene oxide gas, steam, and electron beam methods of sterilization.

By proper selection of the entangling screen, the fabric may be given a fine linen like pattern and texture. This fabric also is post embossed with a matched die pattern at room temperature ; the combination of embossing and fine linen like screen pattern imparts a unique appearance, clothlike feel, bulk, softness and texture to the fabric.

Optionally, a small amount of binder may be incorporated in or applied to the surface of the hydroentangled web to improve its abrasion resistance and reduce linting. A low lint count is an important quality of wipes for use in clean rooms. A wide variety of latex binders, thermoplastic binder fibers and thermoplastic powders are available as binders or wet strength binders.

Fig. 1 is a simplified, diagrammatic perspective view of hydroentanglement apparatus illustrating one specific embodiment of a suitable method for making the nonwoven fabric of this invention from one or more wet-laid webs.

Fig. 2 is a bar graph illustrating the absorption rate of samples, the test results of which are reported in Table I.

Fig. 3 illustrates graphically the absorbency under load of the samples reported in Table I.

Fig. 4 is a vertical cross-sectional view along the plane 4-4 of Fig. 5 illustrating on an enlarged scale a dry hydroentangled web pressed between the surfaces of matched die embossing rolls.

Fig. 5 is a plan view of an enlarged section of a web embossed in a preferred embossment pattern.

Fig. 6 is a developed cross-sectional view on an enlarged scale illustrating the surfaces of matched dies and their relationship to the web during the embossing process.

Preformed wet-laid webs 11, 12, 13 and 14 made up of an intimate blend of staple fibers and wood pulp are drawn from supply rolls 15, 16, 17 and 18 over guide rolls 121, 122, 123 and 124 by feed rolls 126 and 127 onto a foraminous carrier belt 128. A woven polyester screen formed of a flexible material is suitable as a carrier belt for transporting the wet-laid webs through the hydroentanglement apparatus to form a uniform fabric web 40. The carrier belt 128 is supported on rolls 131, 132, 133 and 134, one or more of which may be driven by suitable means, not illustrated. A pair of rolls 136 and 137 remove the hydroentangled web fabric 40 from the belt 128 for drying and subsequent embossing treatment. Several orifice manifolds 141, 142 and 143 are positioned above the belt 128 to discharge small diameter, high velocity jet streams of water onto the wet-laid webs and resulting composite web 40 as it moves from rolls 126 and 127 to rolls 136 and 137. Each of the manifolds 141, 142 and 143 is connected with a source of water under pressure through conduits 146, 147 and 148, and each is provided with one row of 0.005 inch (0.127 mm) diameter orifices spaced on 0.025 inch (0.635 mm) centers (to provide 40 orifices per linear inch) along the lowermost surface of each of the manifolds. The spacing between the orifice outlets of the manifolds and the web directly beneath each manifold is preferably in the range of from about one-quarter inch (6.35 mm) to about one-half inch (12.7 mm). Water from jets discharged from the orifices which passes through the web 40 and the screen 128 is removed by vacuum boxes 151, 152 and 153. Although only three manifolds are illustrated, representing three separate pressure stages, as many as fourteen manifolds are preferred, the first two operating at a manifold pressure of about 200 psig (1380 KPa) and the remainder at pressures in the range of 400 to 800 psig (2760 to 5520 KPa) as described in the specific examples herein.

In accordance with this invention, after the hydroentangled web 40 is dried by conventional drying apparatus, not illustrated, the dried web is embossed with matched embossing dies as illustrated in Figs. 4 to 6. An enlarged section of embossed web 40 is illustrated in Fig. 5 in a plan view with an arrow indicating the machine direction of the web. The rows of embossments 42′ are depressed into the upper surface of the hydroentangled web 40 while alternate rows of embossments 44′ are impressed into the web from its opposite side. This type of embossing is known in the art as "perfembossing".

Fig. 4 is a cross-sectional view, greatly enlarged in scale, of the embossed web of Fig. 5 taken along the plane 4-4 of Fig. 5. As illustrated, the impressions from the bosses or "knuckles" of the embossing tool are spaced apart by a distance greater than the width of the boss. This produces a uniform pattern on both sides of the web.

Fig. 6 is a developed cross-sectional view taken along the plane 6-6 of Fig. 5 illustrating the relationships of the web and the embossing dies during the process of embossment. For the purpose of simplification and clarity of illustration, the surfaces of the cylindrical embossing rolls 43 and 45 are shown as flat plates 43 and 45. Fig. 6 is in three sections A-A, B-B and C-C, corresponding to planes A-A, B-B and C-C of Fig. 4. The bosses 42 extending downward from the surface 43 of the upper embossing roll form depressions 42′ of Figs. 4 and 5 in the upper surface of web 40 while the bosses 44 extending upward from the surface 45 of the lower embossing roll form impressions 44′ of Figs. 4 and 5 on the lower surface of web 40.

Steel-to-steel matched embossing rolls marketed by Industrial Engraving Company under the trade designation I-8306 are capable of operation to produce the patterns illustrated in Fig. 5. The embossing roll 43 may be provided with continuous raised lands 46 interconnecting bosses 42, and embossing roll 45 may be provided with continuous raised lands 48 interconnecting bosses 44.

Embossment of the hydroentangled web 40 in this manner improves absorbency and appearance of the finished product and greatly improves the hand of the fabric as demonstrated in Examples 7 and 8, herein below.

Example 1

In this example, a 2/1 twill, 31 x 25 mesh, polyethylene terephthalate (PET) screen from National Wire Fabric Corporation having a warp diameter of 0.0199 inch (0.505 mm) and a shute diameter of 0.0197 inch (0.500 mm) with an open area of 22.9 percent and an air permeability of 590 cubic feet (16.7 m3) per minute is used as the carrier belt for the hydroentanglement operation.

A wet laid 3.8 oz./sq. yd. (79 lb./ream) (129 g/m^2) web is prepared from a mixture of 60 weight percent long fiber northern softwood kraft pulp and 40 weight percent of 1.5 denier by three-quarter inch polyethylene terephthalate (PET) staple fibers. The web is passed at a speed of 240 ft./min (73 m/min.) under water jets from a manifold provided with a row of 0.005 inch (0.127 mm) diameter orifices spaced 0.025 inch (0.635 mm) apart extending across the full width of the web. The fibers in the web are

hydroentangled by subjecting them to two passes under the rows of water jets operating at a manifold pressure of 200 psig (1380 KPa), four passes at a manifold pressure of 400 psig (2760 KPa), and eight passes at a manifold pressure of 800 psig (5520 KPa).

Properties of the resulting hard finished nonwoven fabric produced in this example are shown in the accompanying Table I (Specimen A) in comparison with the properties of several commercially available products including the conventional "huck" (huckaback) cotton towels.

TABLE 1

SPECIMEN		A	B(1)	C(2)	D(3)
Basis Weight					
(oz/sq yd)		3.8	3.1	2.25	7.8
(g/m^2)		129	105	76.4	264.8
Thickness (mils)		35	25	18	57
Grab Tensile (1b)					
MD Wet		19	6	5	97
CD Wet		19	5	5	82
Grab Elongation (%)					
MD Wet		90	25	34	34
CD Wet		100	50	26	26
Elmendorf Tear (g)					
MD Wet		1600	200	80	4000
CD Wet		1900	220	50	4000
Absorption Capacity (g/g)		6.2	4.2	3.6	3.2
Area Capacity (g/m^2)		850	450	280	936
Wicking Rate (g/g/sec) x 1000		38.7	29.9	26.8	16.8
Bulk Density (cc/g)		8.2	6.1	5.8	4.8
Flammability (sec)					
NFPA-702	- MD	6.5	5.5	4.3	16.8
	- CD	7.4	6.5	4.4	25.6

(1) Sample B is a hydroentangled 100 % rayon fiber towel containing a latex binder sold under the trade name J & J Surgisorb, by Johnson & Johnson, New Brunswick, New Jersey.
(2) Sample C is a scrim reinforced tissue product having two to four plies of wood cellulose tissue reinforced by an internal web of synthetic fiber sold under the trade name Kaycel by Kimberly Clark Corporation of Neenah, Wisconsin
(3) Sample D is a generic huckaback woven cotton towel.

It will be evident from the foregoing example that the nonwoven fabric of this invention (Sample A) provides superior absorption capacity as compared with conventional huckaback woven cotton towels (Sample D) and currently available non-woven fabrics represented by Samples B and C. The absorption capacity of Sample A of our nonwoven fabric is twice that of the huck towel, on a weight basis while the

nonwoven fabric is approximately 50 % lighter in basis weight. Even at the lower basis weight, the fluid area capacity of the nonwoven fabric (Sample A) compares favorably with that of the huck towel (Sample D).

Examples 2 to 5

In theses examples, fabrics are produced by forming wet-laid webs of varying fiber compositions and subjecting the wet-laid webs to the conditions described in Example 1. The forming screen in Examples 2 and 3 is the same as that of Example 1. In Example 4, the forming screen is made up of PET fibers with a warp diameter of 0.024 inch (0.609 mm) and a shute diameter of 0.028 inch (0.711 mm) and an air permeability of 555 cfm (15.7 m^3/min). The forming screen of Example 5 is made up of PET fibers with a warp diameter of 0.042 inch (1.06 mm) inch, and shute diameter of 0.049 inch (1.24 mm).

In Examples 2 and 3, the fabric is made up from four layers of preformed and dried wet-laid substrate webs as illustrated in Fig. 1 of the drawings. The PET component of Examples 2 and 3 is three-quarters inch (19.05 mm), 1.5 denier staple fibers in Examples 4 and 5, the PET fibers are three-quarters inch (19.05 mm) by 1.2 denier. In Examples 4 and 5, the fabric is made up from two layers of preformed and dried wet-laid substrate webs.

Physical properties of the finished fabrics are shown in Table 11. The data from Specimen A of Example 1 are repeated for comparison purposes.

TABLE II

SPECIMEN EXAMPLE		A 1	E 2	F 3	G 4	H 5
Fiber Composition						
(wt. %) Pulp		60	50	75	60	60
PET		40	50	25	40	40
Forming Screen						
Mesh (per in)		31x24	31x25	31x25	22x23	20x16
Twill		2/1	2/1	2/1	2/1	2/1
Basis Weight (oz/sq yd)		3.8	3.8	3.8	3.8	3.8
Thickness (mils)		35	27	38	44	48
Peak Grab Tensile						
Dry (1bs)	MD	42.3	25.0	32.0	40.5	41.7
	CD	39.6	16.0	22.0	40.7	35.3
Wet (1bs)	MD	19	12.0	14.0	26.5	22.6
	CD	19	6.0	10.0	26.4	22.9
Peak Grab Elongation						
Dry (%)	MD	39.3	53.1	47.8	57.3	53.3
	CD	48.2	94.5	66.3	62.4	71.7
Dry (%)	MD	90	81.9	54.5	79.8	86.7
	CD	100	102.6	107.4	85.4	98.9
Elemndorf Tear						
Dry (g)	MD	1470	1100	950	1650	1633
	CD	1065	850	1083	1483	1833
Wet (g)	MD	1600	1100	950	2733	3800
	CD	1900	580	583	3133	2475
Mullen Burst (psi)		122	63	68	87	93
Air Permeability (cfm)		-	230	98	223	248
Absorptive Capacity (g/g)		6.2	7.2	5.97	7.55	7.57
Area Capacity (g/m^2)		850	802	802	866	833
Wicking Rate (g/g/sec) x 1000		38.7	46.6	32.9	20.78	34.45
Flammability (sec)						
NFPA-702	MD	6.5	4.2	5.2	7.6	9.4
	CD	7.4	5.3	5.7	7.4	11.0

Example 6

A fabric is made up from a wet-laid web composed of 60 weight percent cotton linters and 40 weight percent three-quarter inch by 1.2 denier polyethylene terephthalate (PET) staple fibers on the forming

screen and under the conditions described in Example 1.

Physical properties of the product are listed in Table III.

TABLE III

Example		6
Basis Weight	(oz/yd²) (g/m²)	4.9 166.4
Thickness (mils)		43.6
Peak Grab Tensile		
Wet (1b)	MD CD	21.3 20.0
Peak Grab Elongation		
Wet (%)	MD CD	84.5 83.1
Elmendorf Tear		
Wet (g)	MD CD	3100 3800
Absorption Capacity (g/g)		5.59
Wicking Rate (g/g/sec) x 1000		7.34
Area Capacity (g/m²)		854
Flammability (sec)		
NFPA-702	MD CD	10.9 9.2

In the following examples, nonwoven hydroentangled fabrics were produced from wet laid webs, dried and embossed between steel-to-steel matched embossing rolls. The matched steel rolls supplied by Industrial Engraving Co. were provided with an elongate hexagonal protuberances or knuckles as illustrated in Fig. 4. In these examples, the embossing rolls were adjusted to produce a center float half step perforation pattern as illustrated in Fig. 5. The knuckles on each of the embossing rolls have an overall longitudinal base dimension in the machine direction of 0.114 inch (2.89 mm), a base width in the cross machine direction of 0.030 inch (0.762 mm), a height of 0.046 inch (1.168 mm), a machine direction spacing of 0.029 inch (0.736 mm), and a spacing of 0.148 inch (3.659 mm) in the cross machine direction. The sides of the knuckles have a slope of 3° from the vertical plane of radius of the roll ; the slope of the end of a knuckle is 25° relative to the vertical or radius of the roll.

Example 7.

In this example, a nonwoven fabric is produced by forming a wet-laid substrate (95 lb./ream) (155.2 g/m²) of 60 % Northern softwood kraft and 40 % of three-quarter inch by 1.5 denier PET staple fiber. The forming screen in this example is the same as that of Example 1. The web was subjected to two passes under the rows of water jets operating at a manifold pressure of 200 psig (1380) KPa), four passes at a manifold pressure of 800 psig (5520 KPa) and four passes at 1600 psig (11040 KPa) affecting intimate entanglement of the wood fibers and staple fibers.

The web was then dried and embossed with matched (Industrial Engraving I-8306) steel-to-steel embossing rolls. We used two levels of penetration of either 25 or 50 mils (0.635 or 1.27 mm) and the rolls were set either at a side contact or center float for both full or half step perforating condition. Absorbent

properties of the resulting finished nonwoven fabric produced in this example are shown in Table IV.

TABLE IV

SPECIMEN EXAMPLE	J (unembossed) 6	K (embossed) 7
Fiber Composition		
Pulp (wt %)	60	60
PET (wt %)	40	40
Basis Weight		
(oz/sq yd)	4.68	4.75
(g/sq m)	158.9	161.3
Bulk* (cc/g)	5.0	6.9
Absorptive capacity		
(g/g)	4.29	4.69
(g/m^2)	682	756
Initial Wicking Rate (g/g/sec) x 1000	5.1	9.8
Absorption Time (sec)	89	83

* Measured under 7 g/cm^2 confining pressure.

Example 8

A wet laid web having a basis weight of 3.8 ounces per square yard (129 g/m^2), as in Example 1, was prepared and dried and then hydroentangled at a speed of 40 feet per minute under two rows of water jets operating at a manifold pressure of 400 psig (2760 KPa), two rows at 900 psig (6210 KPa), and one row at 1200 psig (8280 KPa) followed by two rows at 400 psig (2760 KPa) on the reverse side of the fabric. After drying, the hydroentangled fabric was embossed at 40 feet (12 m) per minute with the pattern illustrated in Fig. 5 at 50 mils (1.27 mm) penetration. Properties of the embossed and unembossed webs are set forth in Table V.

TABLE V

SPECIMEN EXAMPLE	L (unembossed) 6	M (embossed) 7
Basis Weight		
(g/m²)	127	127
(oz/sq yd)	3.74	3.74
Dry Bulk (Load = 7 g/cm²) (cc/g)	6.1	10.5
Wet Bulk (Load = 7 g/cm²) (cc/g)	5.8	9.5
Wet Bulk Under Load (cc/g) (Load = 100 g/cm²)	4.6	6.4
Wet Bulk After Load Removal (cc/g)	5.4	7.8
Wet Bulk Recovery After Removal of Load (%)	17	22
Absorption capacity (g/g)	5	6.7
Area capacity (g/m²)	635	850
Softness (Loop Test)*		
MD	57	23
CD	25	5
Softness (Sensory)**	65	82
Hand Crush (Sensory)**	55	87

* Lower number = softer end product.

** Higher number = softer end product.

With reference to Table 5, it will be observed that the dry bulk (measured under 7 g/cm² confining pressure) of the product was improved by 70 percent. The first value is the bulk of the specimen after absorption of water under a load of 7 g/cm². The second value is determined after placing a load of 100 g/cm² on the wet specimen and the final value is determined after removal of the load. The wet bulk recovery, reported in percent, is calculated from the wet bulk under load and the wet bulk after removal of the load. The wet bulk recovery of the specimens shows that the embossed specimen has the greater resilience. It can be observed that the absorbency per square meter of the product, related to its resilience, increased by more than 33 percent.

Softness of the specimens was measured by the so-called Loop Method and by a sensory softness test panel. The Loop Test Method is designed for determining the softness of flexible sheet materials by measuring the force required to cause a specimen, which was previously formed into a loop and held in a specimen holder, to buckle. In this test, if the treated specimen requires a lower force to bend than untreated specimen, then that specimen is softer. At least five specimens 88.9 mm x 25.4 mm (3.5 in. by 1 in.), in both machine and cross direction are selected for testing and the results averaged. These samples (conditioned at 23 degree F and 50 % RH) were tested by the Loop Softness Tester and the result recorder in Table V. The force required to buckle the embossed specimens, for both machine and cross machine directions, is considerably lower than for the unembossed specimens. The softness of this product was also measured by a group of twenty in-house softness panelists. This test result (Table V) also confirmed the results obtained by the Loop Test Method.

As indicated in Table III, embossment of the hydroentangled dry nonwoven web by this method of embossment enhanced the absorption rate and increased the absorption capacity of the web. In addition, the apparent bulk, softness and hand of the product was comparable to that of the huck towel of Example 1.

From the foregoing examples, it will be seen that the nonwoven fabric of Example 1, Specimen A of Table 1, compares favorably with that produced in Example 5, particularly with respect to wicking rate, area capacity and absorption capacity.

In the foregoing examples, the Elmendorf tear strength, reported in grams is determined by repeated tests on an Elmendorf tear tester using single ply test strips. Thickness, reported in mils, is determined with an Aimes 212.5 loft tester on a single ply of the specimen.

The absorption capacity in Examples 1 to 3 and 6 to 8 is determined by a fluid absorption test method which measures the ability of a material to absorb as much fluid as it will hold without being flooded. A material sample is placed over a sintered glass porous plate and liquid from a reservoir is allowed to flow through the plate as it is absorbed by the material undergoing test. The weight of the reservoir is recorded

before the test and again after the sample no longer absorbs additional fluid and has reached its maximum fluid saturation without flooding. The liquid absorption ratio is calculated and reported as the amount of fluid in grams absorbed per gram of the material sample. Liquid absorption ratio is independent of the sample's actual weight.

The wicking rate is a method used to determine the time elapsed in seconds for a liquid to travel 6 centimeters along a vertically suspended 2.5 x 10 cm test specimen with the lower end in contact with the liquid. The sample weight is recorded before and after the liquid has reached the six centimeter mark. The vertical wicking rate is reported as the ratio of the liquid weight to sample dry weight divided by the time elapsed in seconds (g of liquid/g dry weight of sample/sec). This ratio is then multiplied by 526. The test is repeated on specimens cut from the material in both the machine direction and the cross direction and the average is reported.

The method for determining absorbency under load or wet resiliency properties of nonwoven fabrics measures the absorbency of the material under load ; specifically, it measures the absorbency capacity of the test specimen after successively increasing the load over the sample in 500 gram weight increments. The test is conducted as described above, and absorption capacity is determined in 500 gram increments from 50 grams to 2500 grams load weight.

Area Capacity is a derived number indicating the liquid holding capacity of a sample and is expressed in grams per square meter. Area capacity is calculated by multiplying the absorptive capacity of the test material expressed in grams of liquid per gram of material by the basis weight in grams per square meter.

The Mullen Burst test (ASTM-D3786-802) is used to determine the bursting strength of fabrics and films in a hydraulic diaphragm type bursting tester. The bursting strength is reported in pounds per square inch hydraulic pressure required to rupture a 1.2 inch diameter test specimen by distending it with force applied from one side by a flexible diaphragm of the same diameter as that of the specimen.

Grab Tensile and Grab Elongation are measured by ASTM-D1682-64 test method, to determine the load in pounds and elongation in percent at the break point in a constant rate of extension tester.

Flammability is determined by using NFPA Test Method Number 702.

Claims

1. A method of making a highly absorbent nonwoven fabric consisting essentially of wood pulp and staple length synthetic fibers which comprises forming a wet-laid web containing from about 30 to about 80 weight percent wood pulp and 70 to 20 weight percent staple length synthetic fibers basis the dry weight of the fibers, forming a compacted highly absorbent web of entangled fibers by subjecting the fibers in the wet-laid web to hydroentanglement, and drying said web to form said nonwoven fabric and embossing the hydroentangled web with a matched die pattern at ambient temperature.

2. A method as defined in Claim 1 wherein the wet-laid web contains 55 to 65 weight percent wood pulp and 35 to 45 weight percent staple synthetic fibers, on a dry weight basis.

3. A method as defined in Claim 1 wherein the length of said staple synthetic fibers is in the range of from about one-half inch (12 mm) to about seven eighths inch (22 mm).

4. A method as defined in Claim 1 wherein the diameter of the synthetic fiber is in the range of from about .5 to about 3 denier.

5. A method as defined in Claim 1 wherein the wet-laid web is subjected to the entanglement action of water jets ejected from 0.005 inch (0.127 mm) diameter orifices equivalent to at least two passes at a head pressure 200 psig (1380 KPa), four passes at 600 psig (4140 KPa) and eight passes at 800 psig (5520 KPa).

6. A method as defined in Claim 5 wherein the weight of the nonwoven fabric is in the range of from about three to four ounces per square yard (102 to 135 g/m^2).

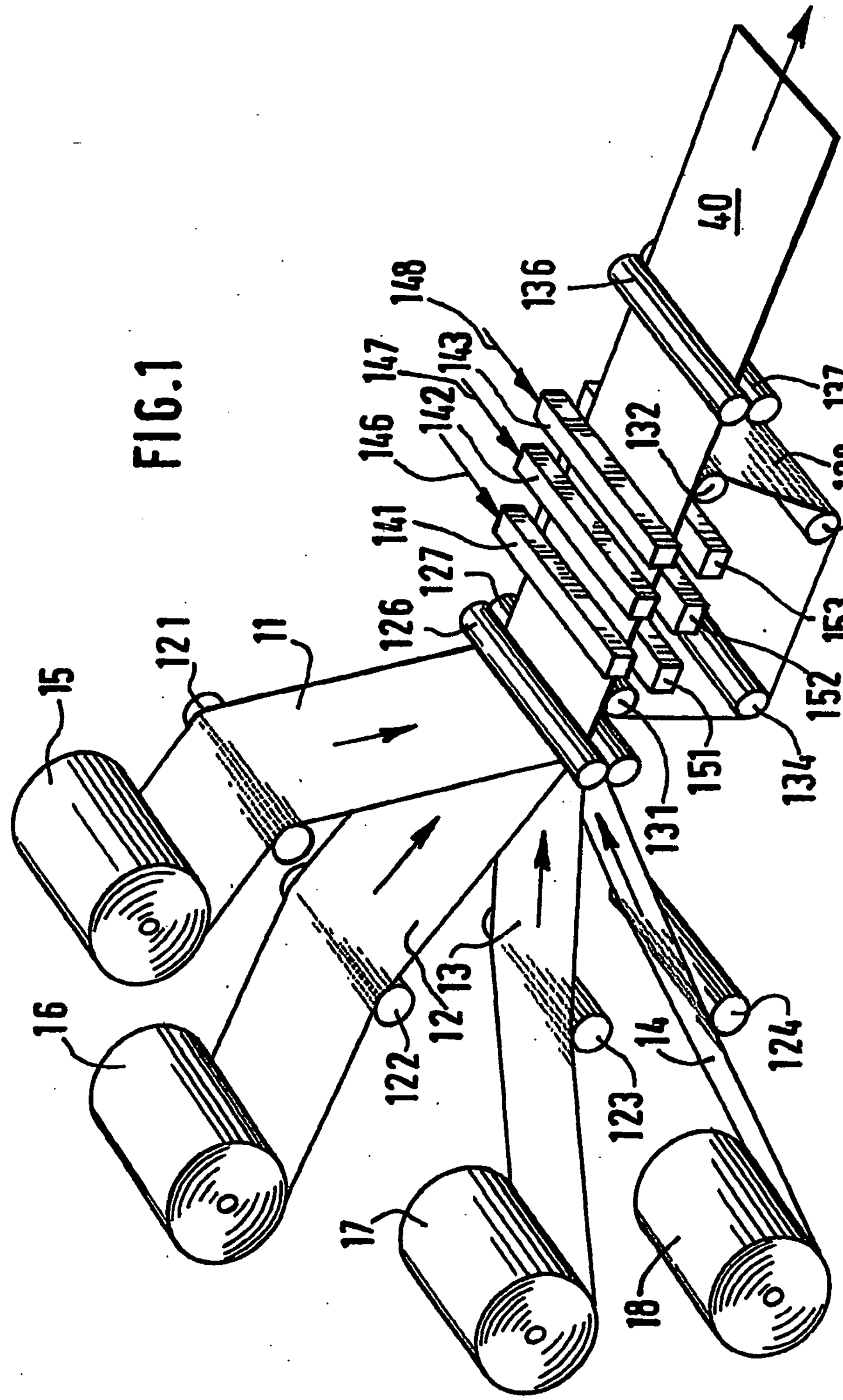
7. A method of making a highly absorbent nonwoven fabric consisting essentially of wood pulp and staple synthetic textile fibers free from added binders which comprises laminating a plurality of wet-laid webs each containing 50 to 75 weight percent wood pulp and 25 to 50 weight percent staple synthetic fibers, combining said webs into a single compacted highly absorbent web of entangled wood pulp fibers and synthetic fibers by subjecting the laminated webs to hydroentanglement, drying and embossing the hydroentangled webs with a matched die pattern at ambient temperature to form a highly absorbent fabric.

8. A method of making a nonwoven fabric according to Claim 7 wherein the dry weight ratio of wood pulp to synthetic fibers is in the range of from about 1 to about 3.

9. A method of making nonwoven fabric according to Claim 7 wherein the synthetic fiber is a polypropylene, nylon or polyester fiber.

10. A method of making a nonwoven fabric as defined in Claim 7 wherein the dry hydroentangled fabric has a basis weight in the range of from about 3 to about 10 ounces per square yard (102 to 339 g/m^2).

11. A method of making a nonwoven fabric as defined in claim 7 wherein the wet laid webs are dried prior to lamination and have a basis weight in the range of 1 to 4 ounces per square yard (33,9 g/m^2 to 135 g/m^2).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40

FIG.1

FIG.2

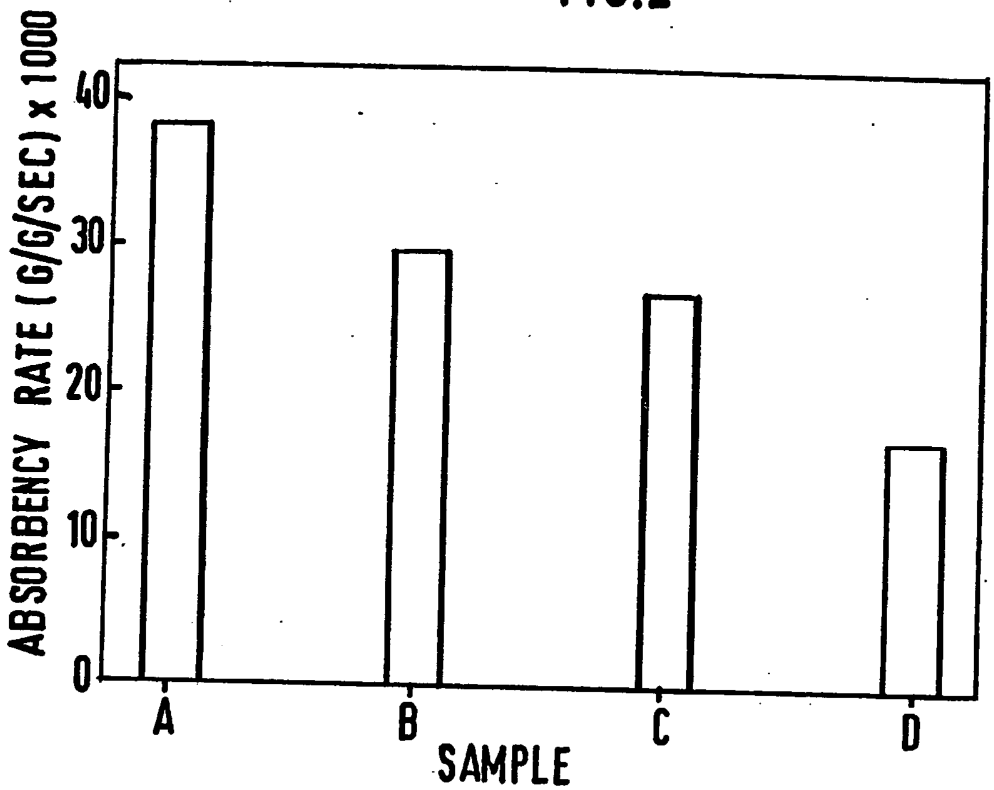
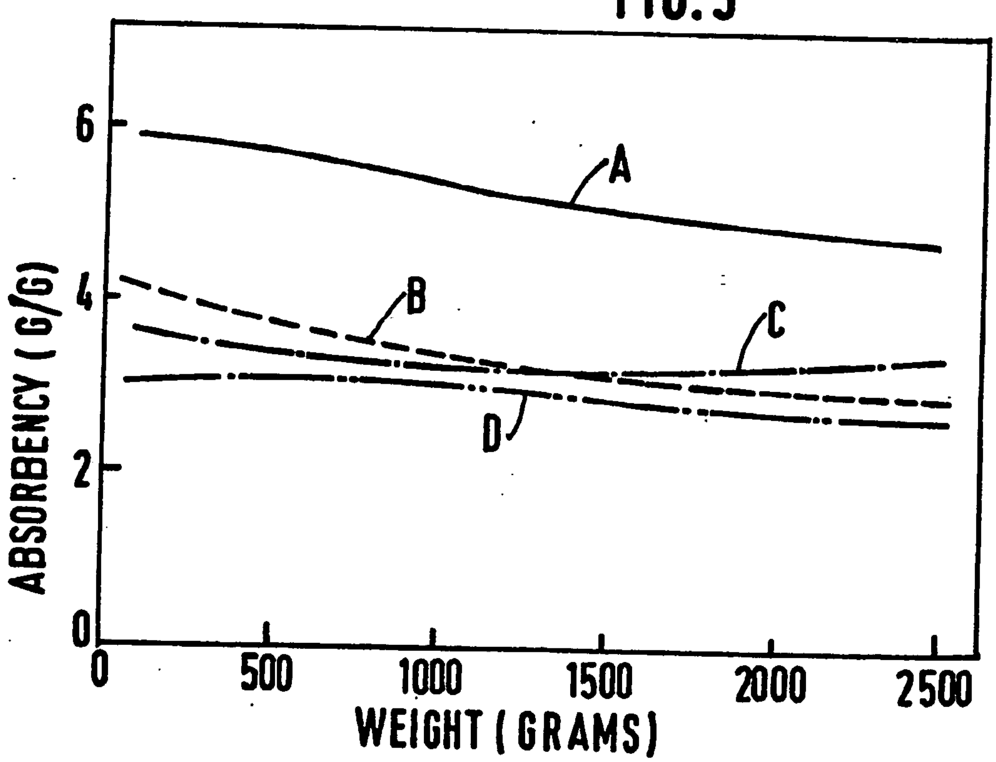

ABSORBENCY RATE (G/G/SEC) x 1000
40
30
20
10
0
A
B
C
D
SAMPLE

FIG.3


ABSORBENCY (G/G)
6
4
2
0
A
B
C
D
0
500
1000
1500
2000
2500
WEIGHT (GRAMS)

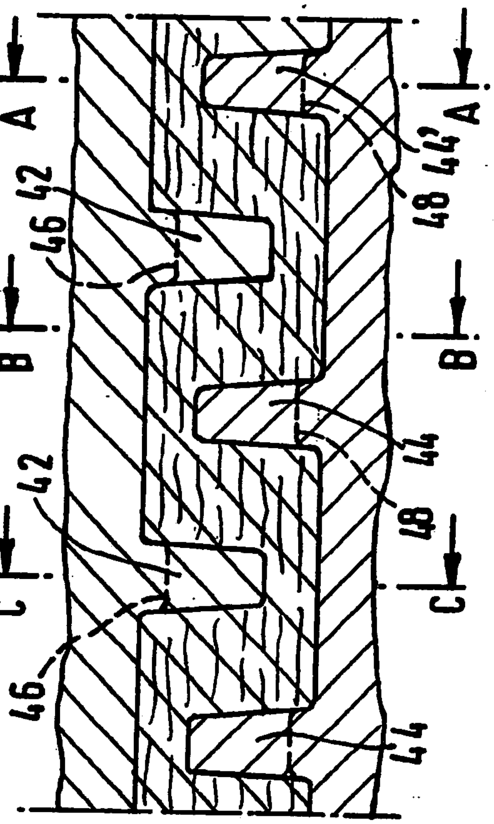


FIG.4

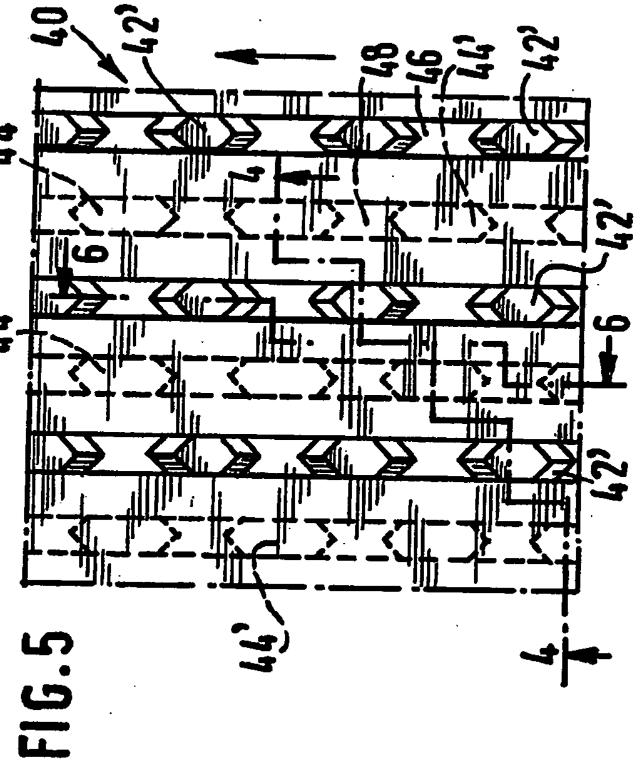


FIG.5

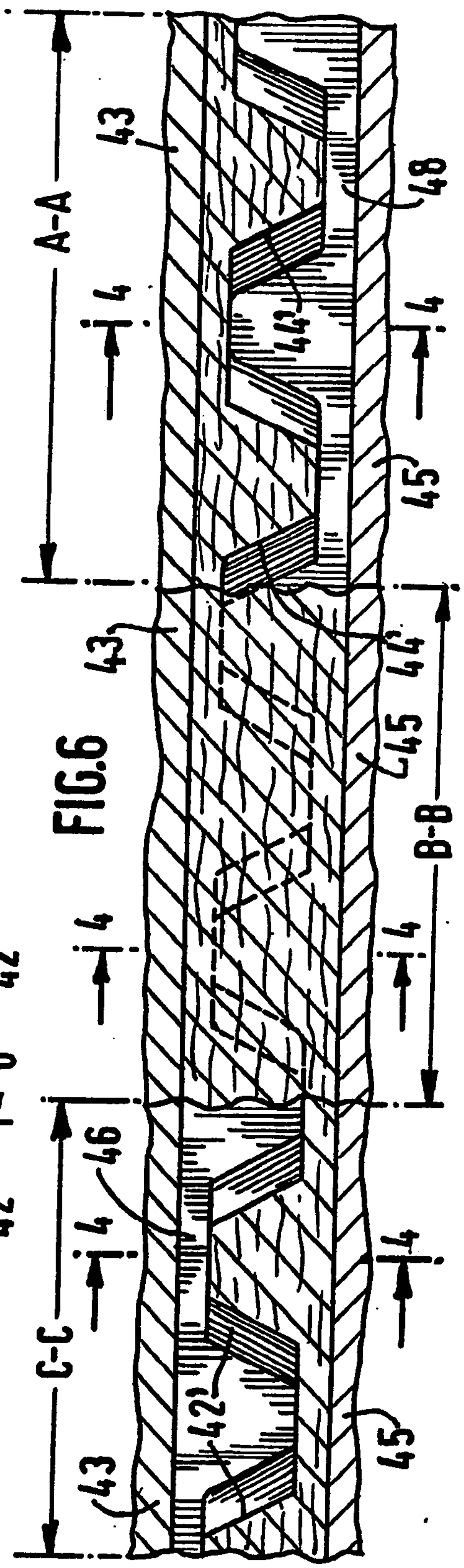


FIG.6